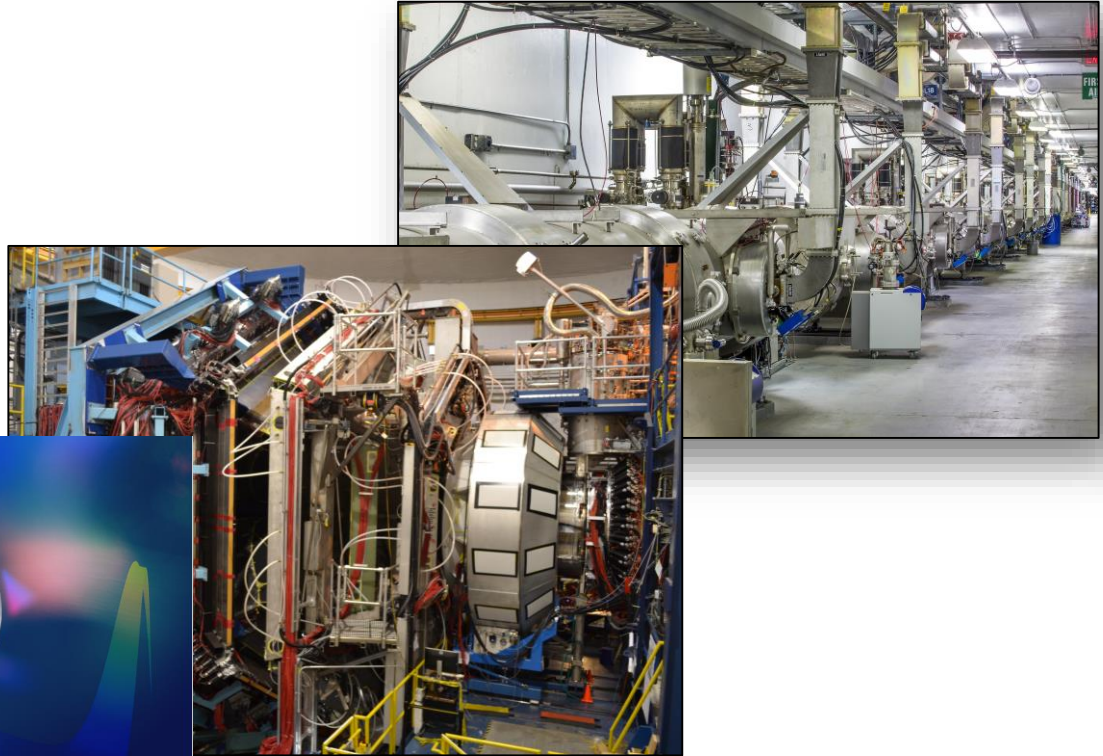
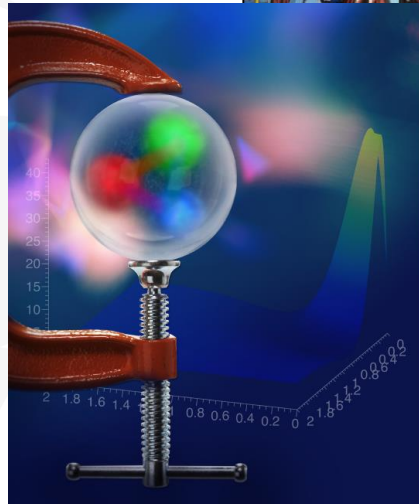


Strong Interaction and Hadron Physics

Experimental

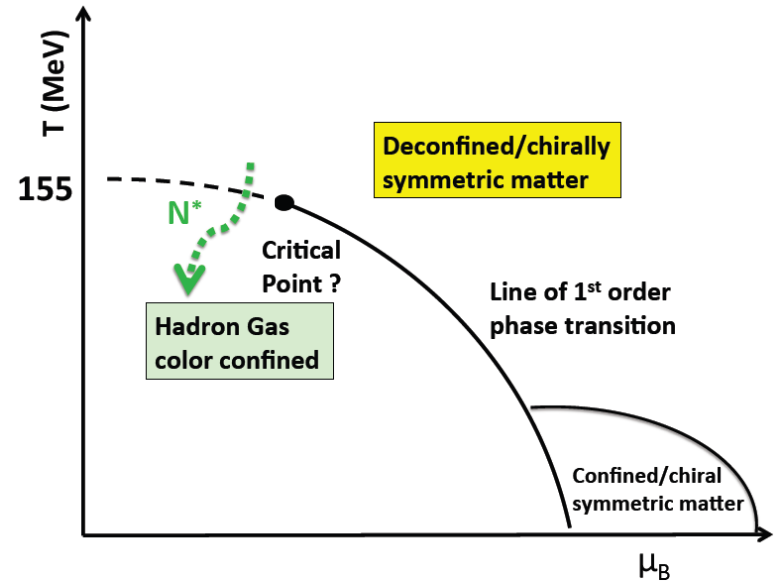
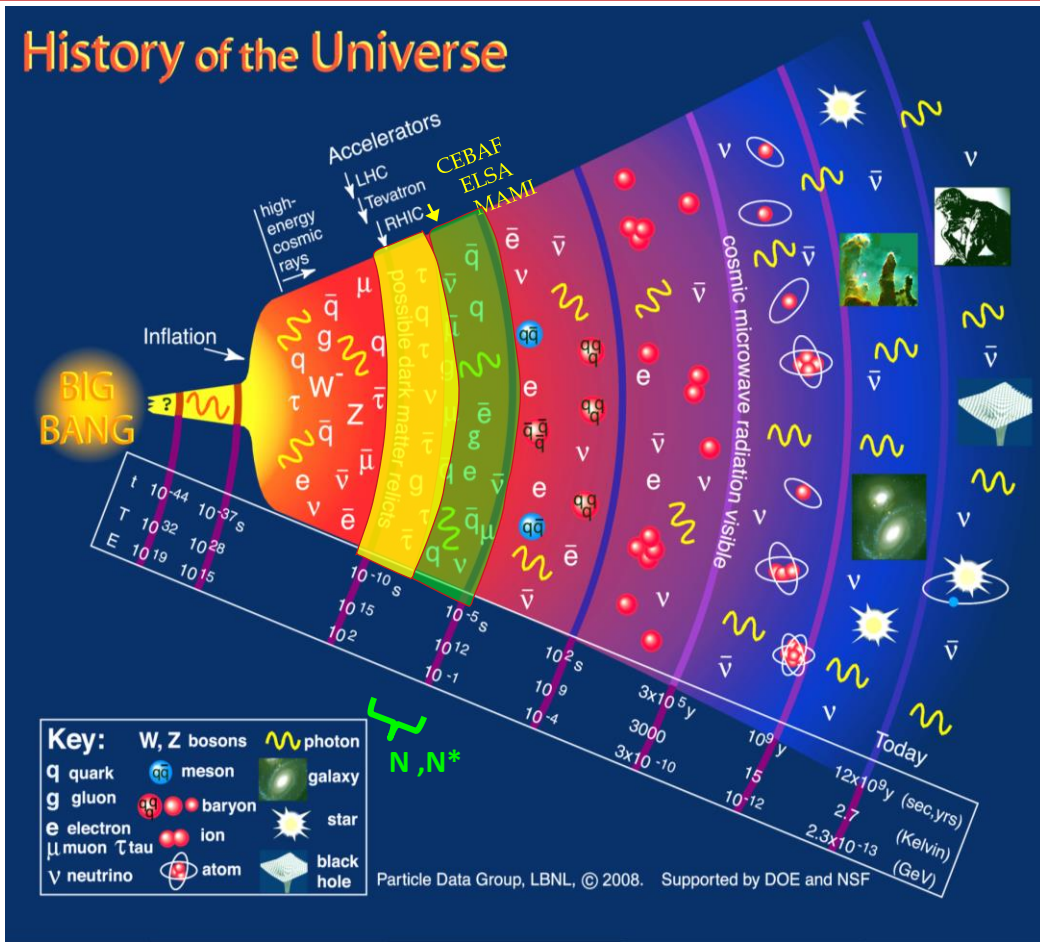
Latifa Elouadrhiri
Jefferson Lab

July 11, 2018



The Emergence of Confinement

History of the Universe



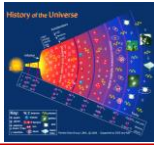
Dramatic events in the μsec old universe

- Chiral symmetry is broken
- Quarks attain masses dynamically
- Quark confinement occurs

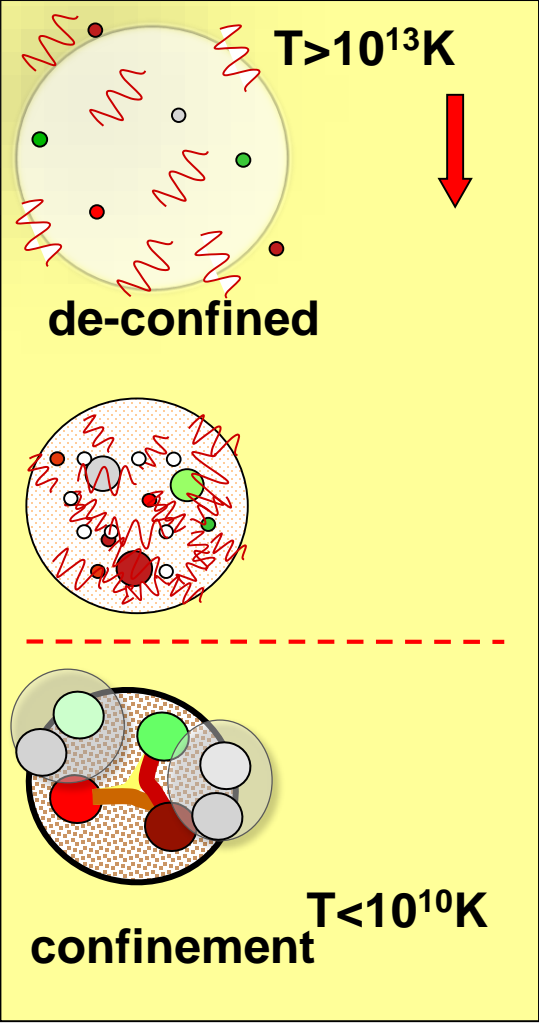
QGP → Hadron gas phase

N^* s existed abundantly 13.7 billion years ago when they were encoded in the proton's "DNA"

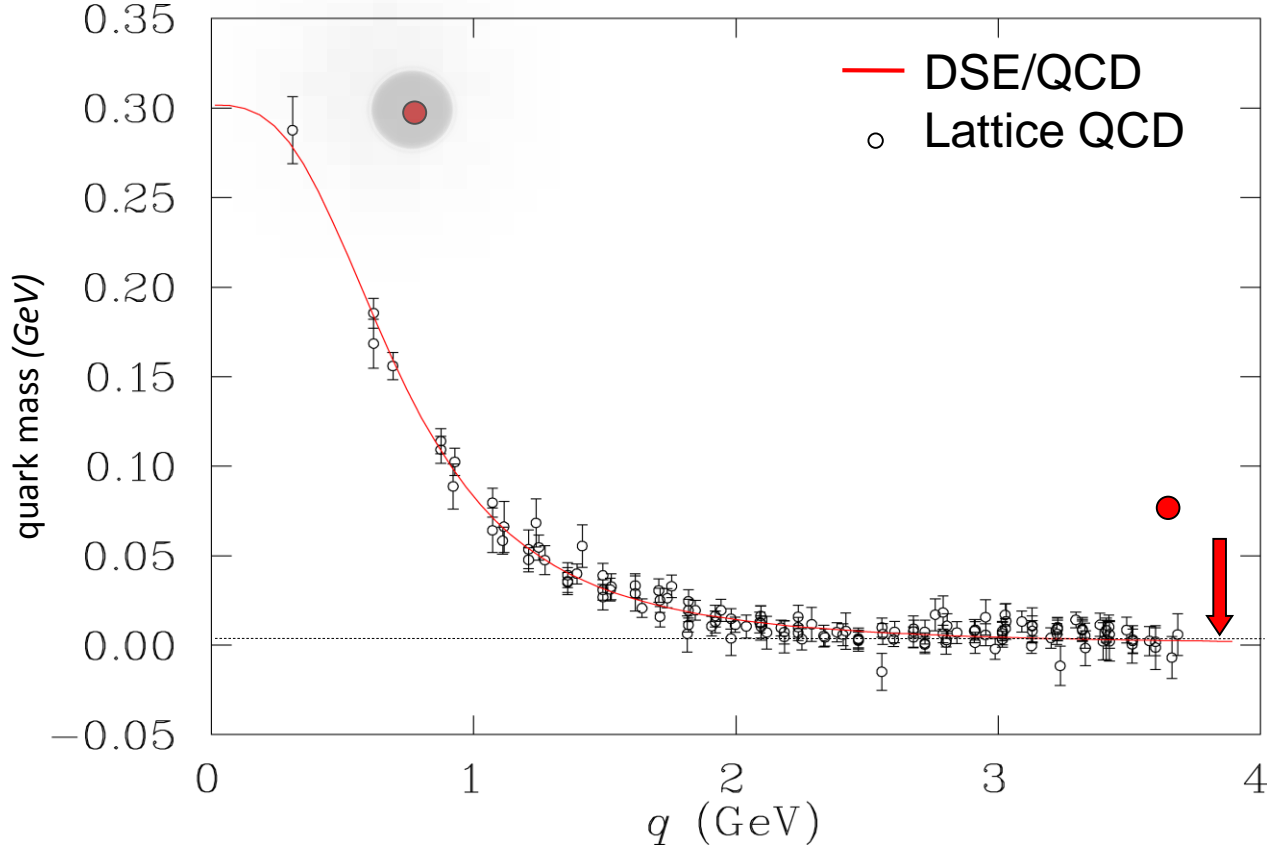
With electron machines we explore these events to unravel the mechanisms of confinement



Light quarks become heavy



As the Universe cools down, quarks develop their gluon cloud and acquire mass dynamically



Bhagwat, M. S., et al., Phys. Rev. C 68, 015203

Bowman, P. O., et al., Phys. Rev. D 71, 054507

What is inside the proton/neutron?

1933: Proton's magnetic moment



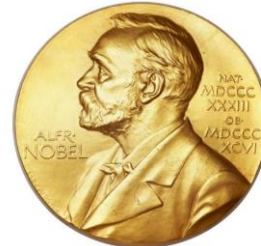
Nobel Prize
In Physics 1943

Otto Stern

"for ... and for his discovery of the magnetic moment of the proton".

$$g \neq 2$$

1960: Elastic e-p scattering

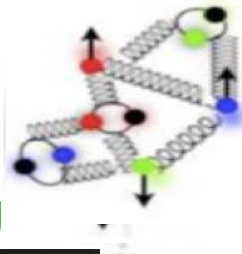


Nobel Prize
In Physics 1961

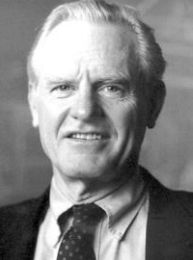
Robert Hofstadter

"for ... and for his thereby achieved discoveries concerning the structure of the nucleons"

Form factors → Charge distributions



1969: Deep inelastic e-p scattering



Nobel Prize in Physics 1990

Jerome I. Friedman, Henry W. Kendall, Richard E. Taylor

"for their pioneering investigations concerning deep inelastic scattering of electrons on protons ..."

1974: QCD Asymptotic Freedom



Nobel Prize in Physics 2004

David J. Gross, H. David Politzer, Frank Wilczek

"for the discovery of asymptotic freedom in the theory of the strong interaction".

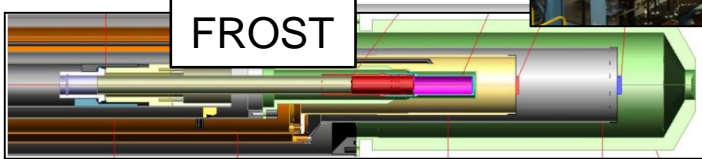
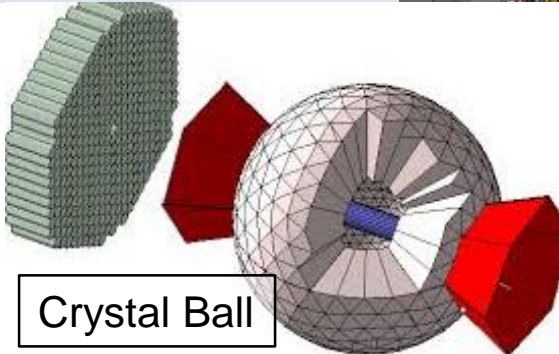
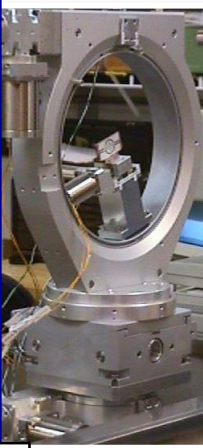
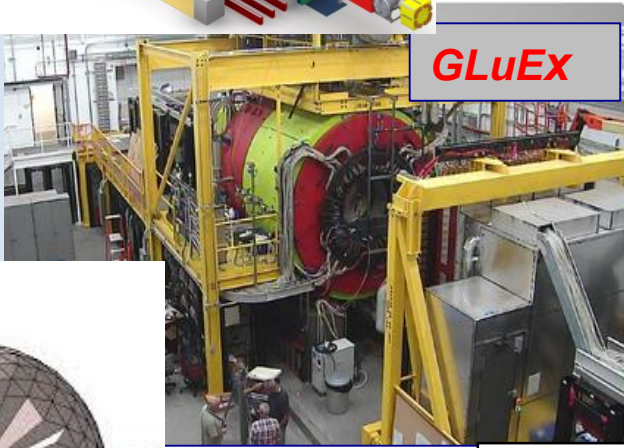
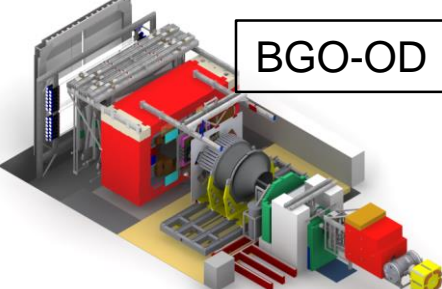
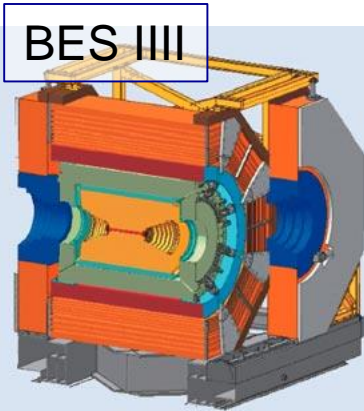
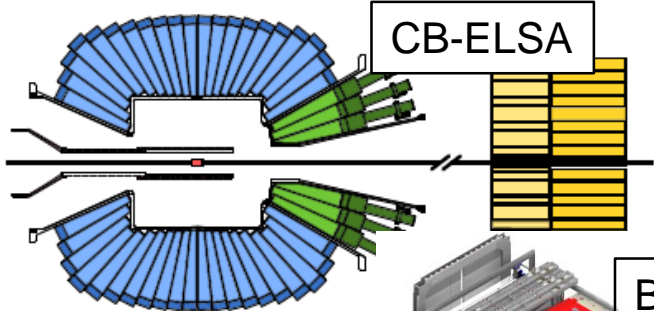
Electromagnetic Interaction to probe Hadrons

- **Spectrum** search for new baryon/meson states ⇨
Symmetries underlying hadronic matter
- **Form factors** ⇨ *measure charge and current (transition) densities and map the transition from soft to hard processes*
- **Structure functions** ⇨ *parton and spin densities*
- **Generalized Partons Distributions (GPDs) and Transverse Momentum Dependence (TMDs)** ⇨ *3D imaging of the quark content, orbital angular momentum*
- **Moments of Generalized Parton Distributions** ⇨ *pressure on quarks and mapping confinement forces*

Electromagnetic Interaction to probe Hadrons

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Symmetries underlying hadronic matter
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- **Moments of Generalized Parton Distributions** \Rightarrow *pressure on quarks and mapping confinement forces*

Facilities & Equipment to Explore Hadron Structure



Jefferson Lab Overview

- One of 17 U.S. Department of Energy National Laboratories
 - Single program focus on Nuclear Physics
- Created to build and operate the Continuous Electron Beam Accelerator Facility (CEBAF), world-unique user facility for Nuclear Physics
- Mission is to gain a deeper understanding of the structure of matter
 - Through advances in fundamental research in nuclear physics
 - Through advances in accelerator science and technology
- In operation since 1995
- **Managed for DOE by Jefferson Science Associates, LLC (JSA)**



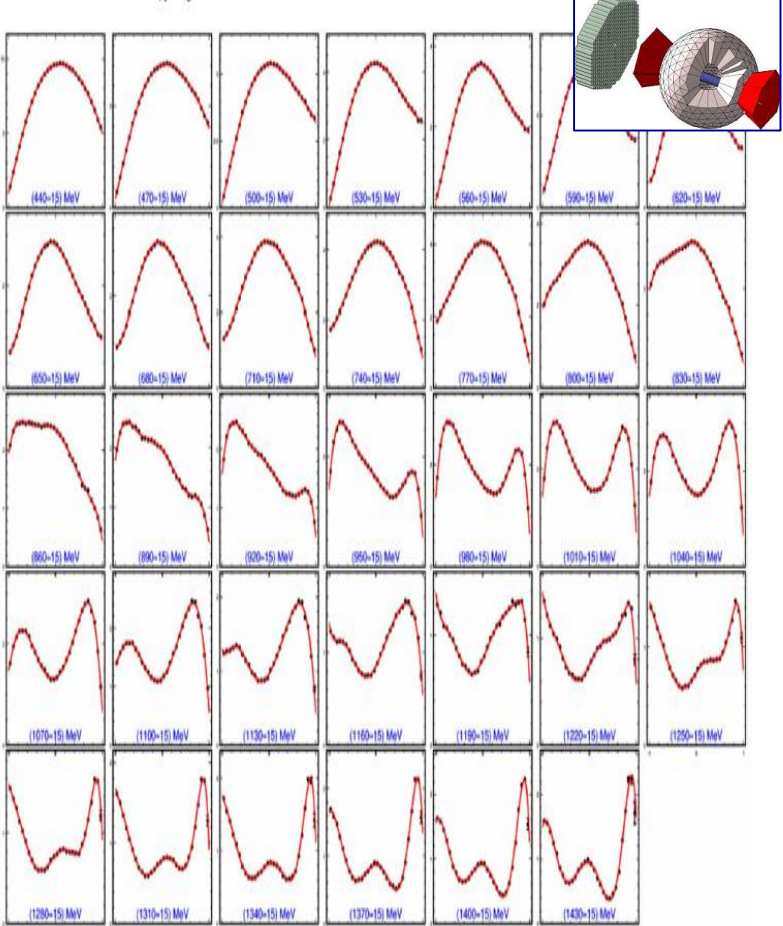
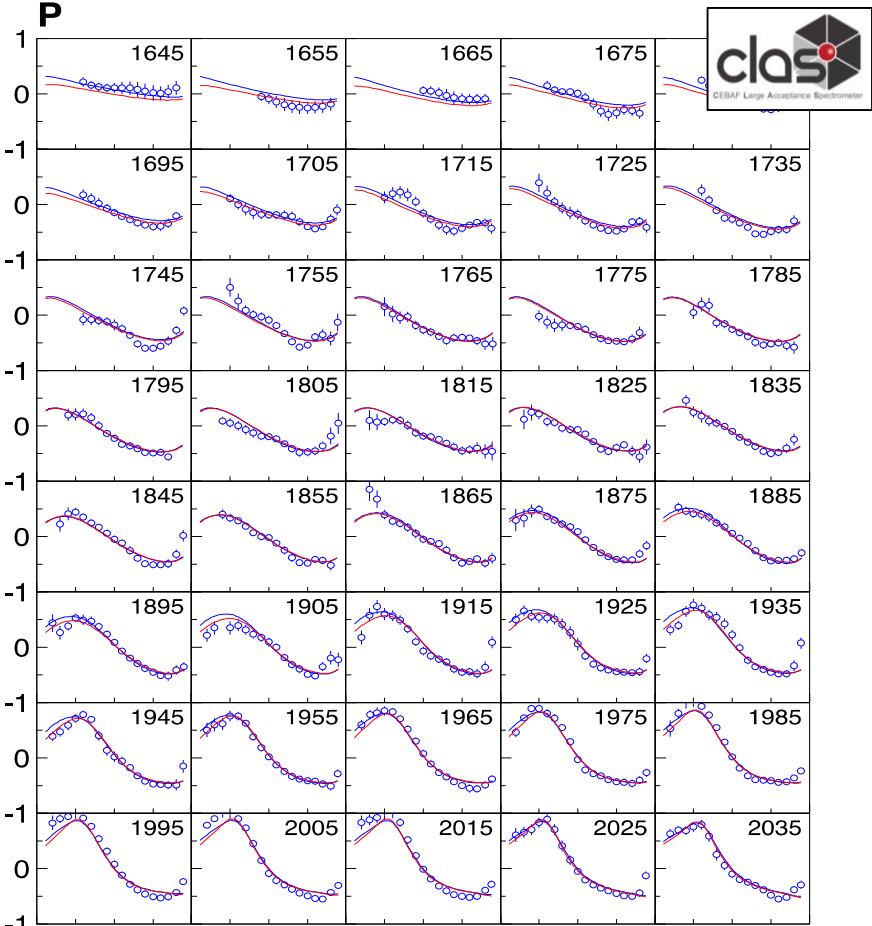
Jefferson Lab by the numbers:

- 700 employees
- 169 acre site
- 1,600 Active Users
- 27 Joint faculty
- **608 PhDs granted to-date (211 in progress)**
- K-12 programs serve more than 12,000 students and 950 teachers annually

Example - Precision data to Establish the N* spectrum

Hyperon photoproduction $\gamma p \rightarrow K^+ \Lambda \rightarrow K^+ p \pi^-$

Differential $p\pi^0$ cross section at MAMI-CB



M. Mc Cracken et al. (CLAS), Phys. Rev. C 81, 025201, 2010

Precision Data to Establish the N^* Spectrum

Multiple nucleon resonances now confirmed;
highlighted in Particle Data Group (PDG) tables.

State $N((\text{mass})J^P)$	PDG pre 2012	PDG 2018
$N(1710)1/2^+$	***	****
$N(1880)1/2^+$		***
$N(2100)1/2^+$	*	***
$N(1895)1/2^-$		****
$N(1900)3/2^+$	**	****
$N(1875)3/2^-$		***
$N(2120)3/2^-$		***
$N(2060)5/2^-$		***
$\Delta(2200)7/2^-$	*	***

**** Existence is certain
*** Existence is very likely
** Evidence of existence is fair
* Evidence of existence is poor

Obtaining an accurate account of the full nucleon resonance spectrum is one of the basis for making progress in our understanding of strong QCD as it relates to light quark sector



**The Nature of Hadron Mass and Quark-Gluon Confinement
from JLab Experiments in the 12-GeV Era**

July 1 (Sun) - 4 (Wed), 2018 | #306, APCTP HQ, Pohang, Korea

The Asia Pacific Center for Theoretical Physics is supported by the Korean Government through the Science and Technology Promotion Fund and Lottery Fund.

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IMPRESSIVE EXPERIMENTAL PROGRESS IN QCD SPIN PHYSICS IN THE LAST 30 YEARS

○ Inclusive spin-dependent DIS

- ➔ CERN: EMC, SMC, COMPASS
- ➔ SLAC: E80, E142, E143, E154, E155
- ➔ DESY: HERMES
- ➔ JLab: Hall A, B and C

○ Semi-inclusive DIS & Deep Exclusive

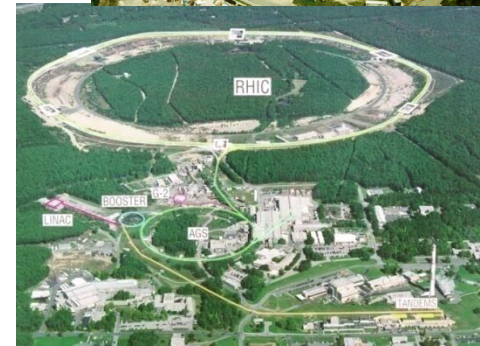
- ➔ SMC, COMPASS
- ➔ HERMES, JLab

○ Polarized pp collisions

- ➔ BNL: PHENIX & STAR

○ Polarized e+e- collisions

- ➔ KEK: Belle



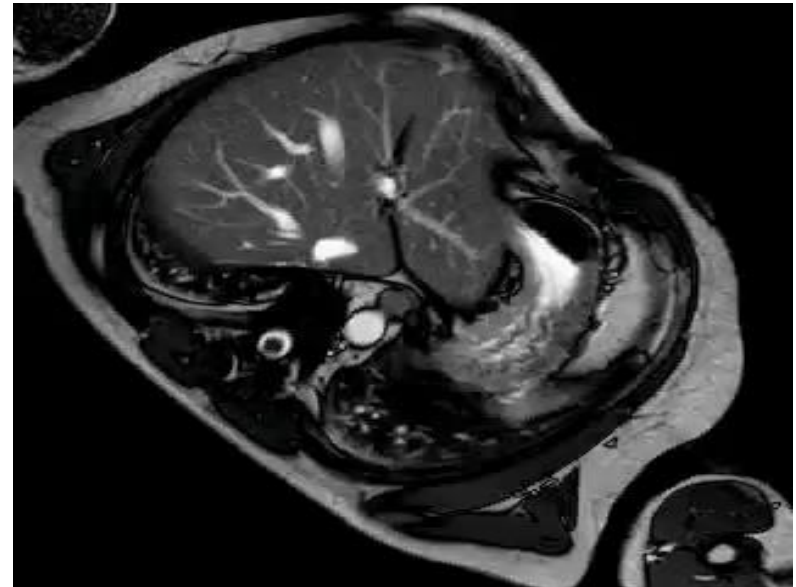
QCD Science Questions

How are the quarks and gluons, and their intrinsic spins distributed in space & momentum inside the nucleon?

What is the role of orbital motion?

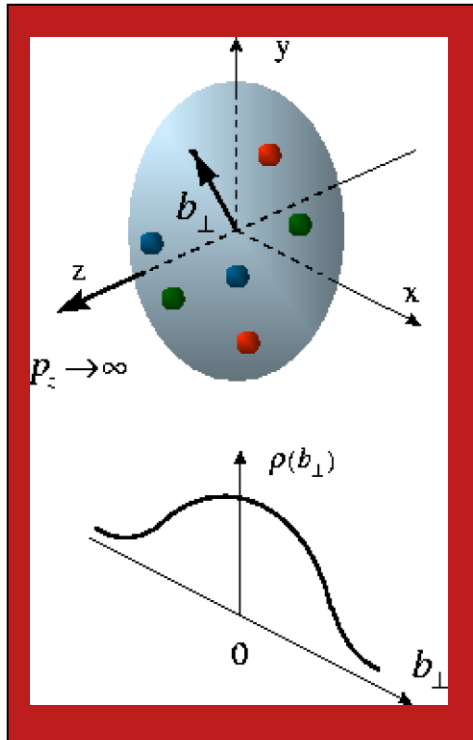
What are Pressure & Forces distributions

Color confinement & its origin?

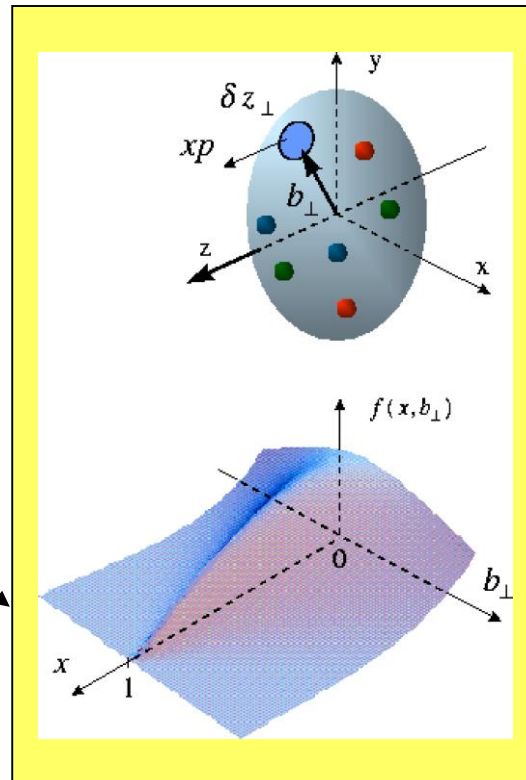


Generalized Parton Distributions (GPDs)

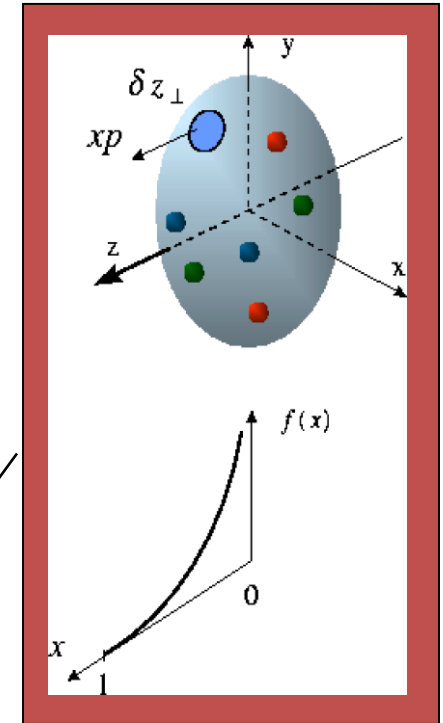
Last 60 years



Last 20 years



Last 45 years



Elastic form factors \rightarrow
Transverse charge & current
 densities $F_1(t), F_2(t)$.

Deeply exclusive processes \rightarrow GPD's
 and **3 D** images in transverse space
 and longitudinal momentum.
 4 GPDs **H, E, \tilde{H}, \tilde{E}** (x, ξ, t)

DIS structure functions
 \rightarrow **Longitudinal** parton
 momentum & helicity
 densities, $F_2(x), g_1(x)$.

GPDs and QCD

The Generalized Parton Distributions (GPDs) provide the theoretical framework to interpret the experimental data

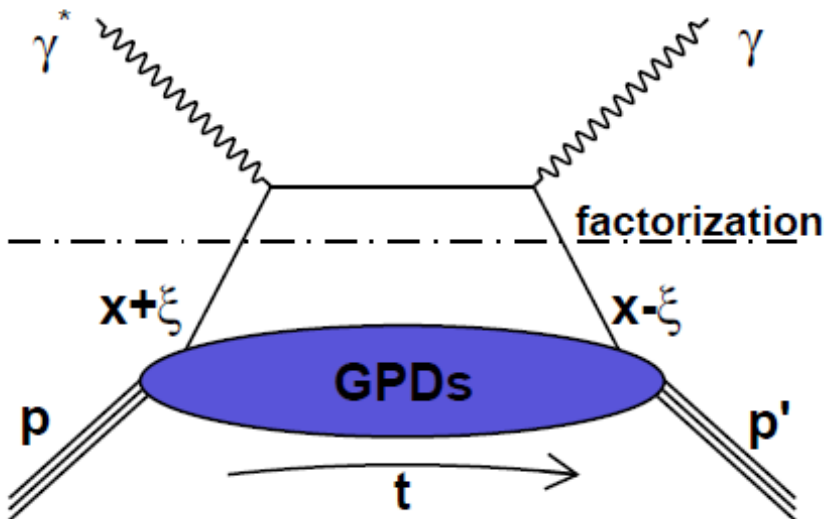
Breakthrough in theory of QCD (1990s): developing **Deeply Virtual Compton Scattering (DVCS) as a tool to characterize the structure of the nucleon within **QCD** and showing how its properties can be probed through experiments.**

D. Mueller (1994), X.Ji (1996), A.Radyushkin (1996)



Deeply Virtual Compton Scattering (DVCS) and GPDs

DVCS and Generalized Parton Distributions



$$\gamma^* p \rightarrow \gamma p'$$

Bjorken regime :
 $Q^2 \rightarrow \infty, x_B \text{ fixed}$

$$t \text{ fixed} \ll Q^2, \xi \rightarrow \frac{x_B}{2-x_B}$$

$$\frac{P^+}{2\pi} \int dy^- e^{ixP^+y^-} \langle p' | \bar{\psi}_q(0) \gamma^+ (1 + \gamma^5) \psi(y) | p \rangle$$

$$= \bar{N}(p') \left[H^q(x, \xi, t) \gamma^+ + E^q(x, \xi, t) i\sigma^{+\nu} \frac{\Delta_\nu}{2M} + \tilde{H}^q(x, \xi, t) \gamma^+ \gamma^5 + \tilde{E}^q(x, \xi, t) \gamma^5 \frac{\Delta^+}{2M} \right] N(p)$$

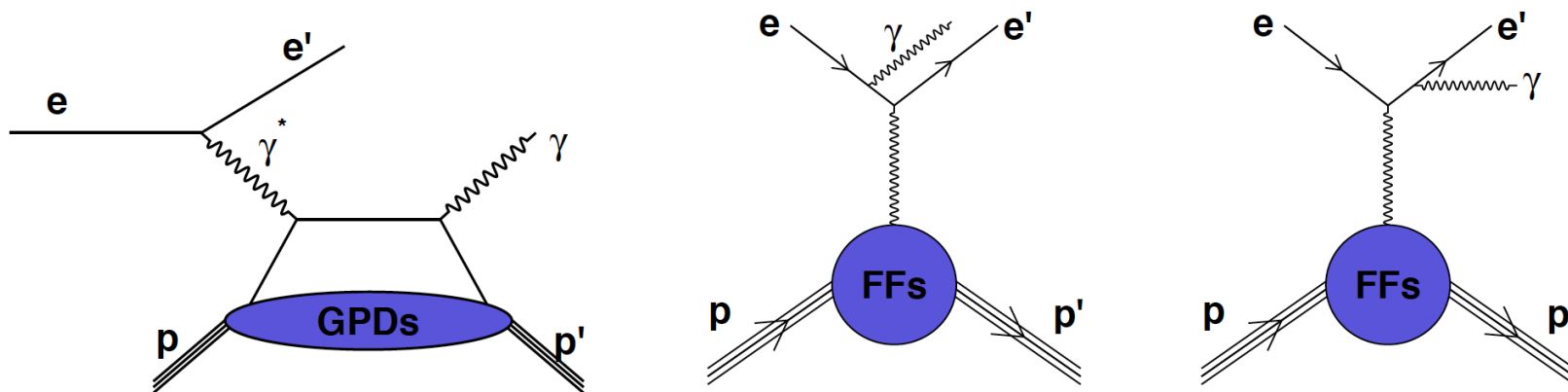
x : average fraction of quark longitudinal momentum

ξ fraction of longitudinal momentum transfer

$H, E, \tilde{H}, \tilde{E}$: Generalized Parton Distributions (GPDs)

3-D Imaging conjointly in transverse impact parameter and longitudinal momentum

Deeply Virtual Compton Scattering - Experiment



The Bethe-Heitler and DVCS processes interfere at the amplitude level :

$$|\mathcal{T}_{\text{BH}} + \mathcal{T}_{\text{DVCS}}|^2 = |\mathcal{T}_{\text{BH}}|^2 + |\mathcal{T}_{\text{DVCS}}|^2 + \mathcal{I}$$

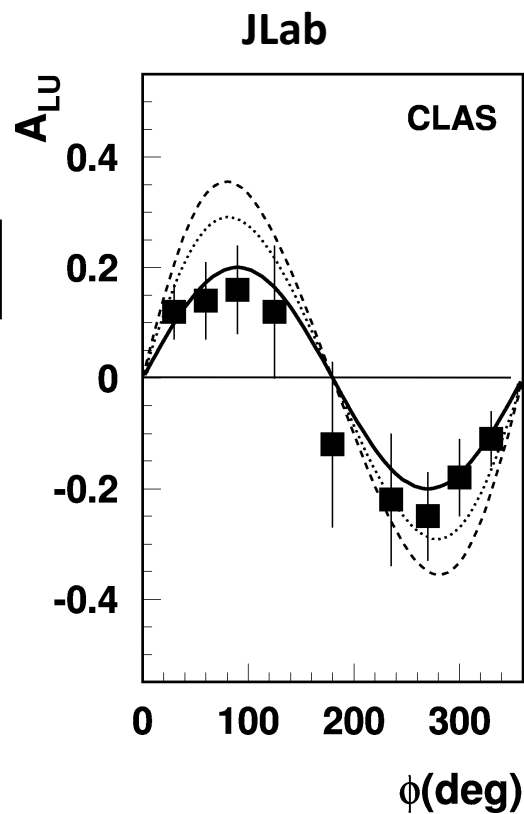
The GPDs enter the DVCS amplitude through a complex integral. This integral is called a *Compton form factor* (CFF).

$$\mathcal{H}(\xi, t) = \int_{-1}^1 H(x, \xi, t) \left(\frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon} \right) dx$$

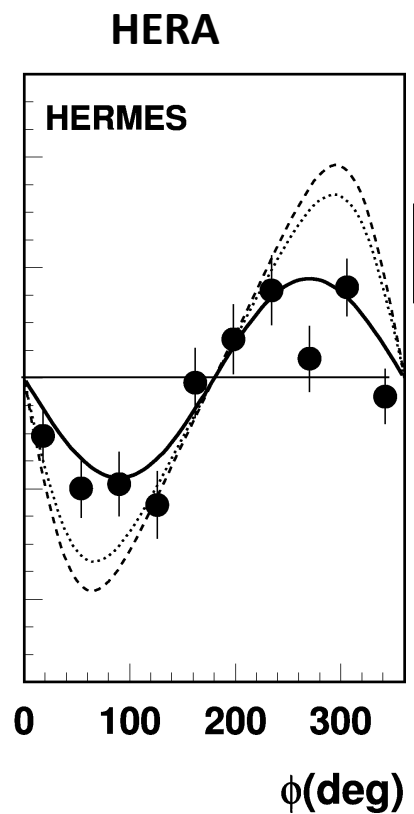
Measured both asymmetries and cross sections

Pioneering experiments observe interference !

$\vec{e}^- p \rightarrow e^- p \gamma$



2001



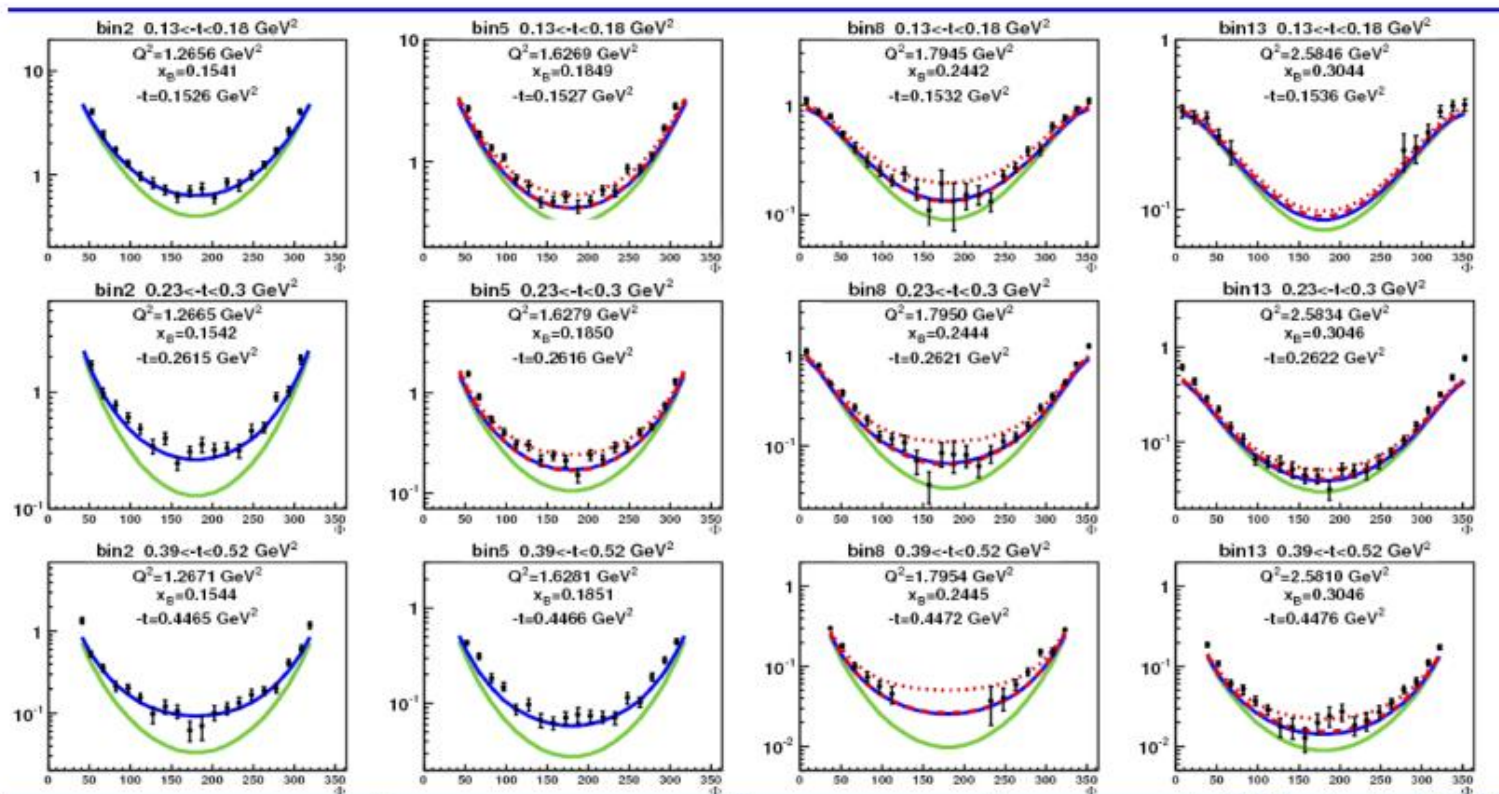
$\vec{e}^+ p \rightarrow e^+ p \gamma$

$$A_{UL} = \alpha \sin\phi + \beta \sin 2\phi$$

\uparrow twist-2 \uparrow twist-3

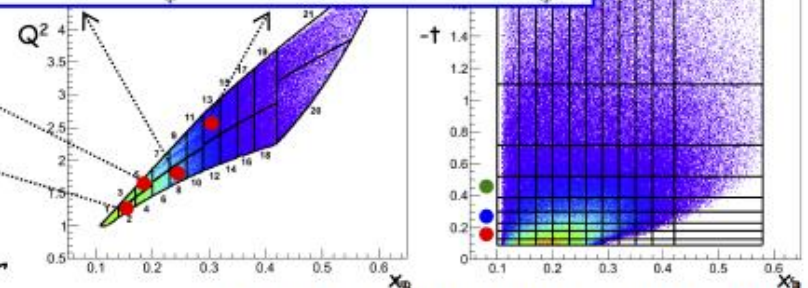
First GPD analyses of HERA/CLAS/HERMES data in LO/NLO consistent with $a \sim 0.20$

DVCS UNPOLARIZED CROSS-SECTIONS



$$\bullet \frac{d^4\sigma_{ep \rightarrow e\gamma}}{dQ^2 dx_B dt d\Phi} \text{ (nb/GeV}^4\text{)}$$

— BH — VGG (H only)
⋯ KM10 - - - KM10a



VGG : Vanderhaeghen, Guichon, Guidal

KM : Kumericki, Mueller

H.-S. Jo et al., PRL 115 212003 (2015)

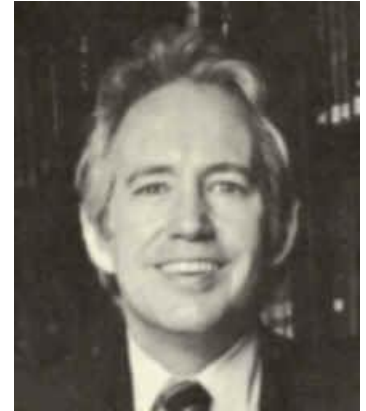
PROBING GRAVITATIONAL PROPERTIES OF THE PROTON?

Energy-Momentum Structure Form Factors of Particles

Heinz Pagels, *Phys. Rev.* 144 (1966) 1250-1260

$$T^{\mu\nu} = \begin{bmatrix} \text{Energy density} & & & \\ T^{00} & T^{01} & T^{02} & T^{03} \\ T^{10} & T^{11} & T^{12} & T^{13} \\ T^{20} & T^{21} & T^{22} & T^{23} \\ T^{30} & T^{31} & T^{32} & T^{33} \\ & \text{Energy flux} & \text{Momentum flux} & \end{bmatrix}$$

Shear stress
Normal stress



Heinz Pagels
(1939-1988)

$$T_{ij}(\vec{r}) = s(r) \left(\frac{r_i r_j}{r^2} - \frac{1}{3} \delta_{ij} \right) + p(r) \delta_{ij}$$

$s(r)$ – distribution of forces (stress)
 $p(r)$ – distribution of pressure

“Contrary to the case of electromagnetism, there is very little hope of learning anything about the detailed mechanical structure of a particle, because of the extreme weakness of the gravitational interaction”

THE GPDS - GFFS CORRESPONDENCE

Nucleon matrix element of the Energy-Momentum Tensor contains three scalar form factors (R. Pagels, 1966) and can be written as (X. Ji, 1997):

$$\langle p_2 | \hat{T}_{\mu\nu}^q | p_1 \rangle = \bar{U}(p_2) \left[M_2^q(t) \frac{P_\mu P_\nu}{M} + J^q(t) \frac{i(P_\mu \sigma_{\nu\rho} + P_\nu \sigma_{\mu\rho}) \Delta^\rho}{2M} + d_1^q(t) \frac{\Delta_\mu \Delta_\nu - g_{\mu\nu} \Delta^2}{5M} \right] U(p_1)$$

$M_2(t)$: Mass distribution inside the nucleon

$J(t)$: Angular momentum distribution

$d_1(t)$: Forces and pressure distribution

GPDs \longleftrightarrow GFFs

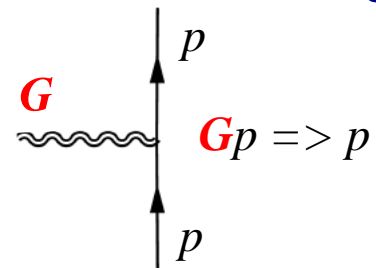
$$\int dx x [\underline{H}(x, \xi, t) + \underline{E}(x, \xi, t)] = 2\underline{J}(t)$$

$$\int dx x \underline{H}(x, \xi, t) = \underline{M}_2(t) + \frac{4}{5} \xi^2 \underline{d}_1(t),$$

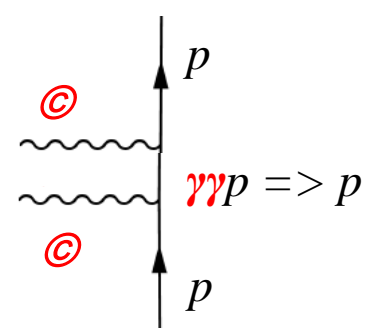
X. Ji, *Phys. Rev. Lett.* 78, 610 (1997)

X. Ji, *Phys. Rev. D* 55, 7114 (1997)

Graviton scattering



DVCS



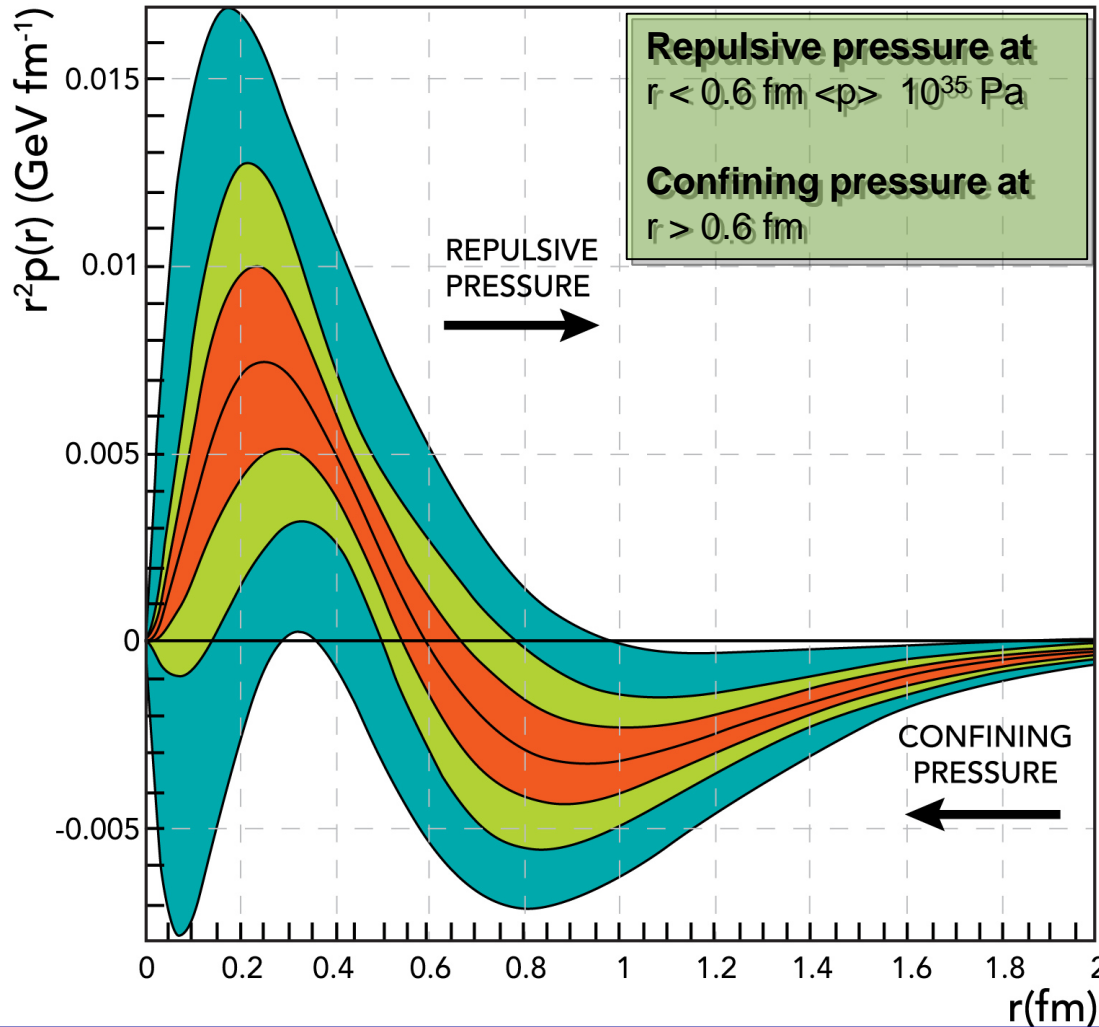
FROM GFF TO MECHANICAL PROPERTIES

Relation of $d_1(t)$ to the pressure distribution given through Bessel integral:

$$\underline{d_1(t)} \propto \int d^3\mathbf{r} \frac{j_0(r\sqrt{-t})}{2t} \underline{p(r)}$$

M. Polyakov, Phys.Lett. B555 (2003) 57

THE PRESSURE DISTRIBUTION INSIDE THE PROTON



nature
International weekly journal of science

Nature 557 (2018) no.7705, 396-399



V. Burkert, L. Elouadrhiri, F.X. Girod

This work opens up a new area of research on the fundamental gravitational properties of protons, neutrons and nuclei, which can provide access to their physical radii, the internal shear forces acting on the quarks and their pressure distributions.

Atmospheric pressure: 10^5 Pa
Pressure in the center of neutron stars $< 10^{34} \text{ Pa}$

IN THE NEWS MAY/JUNE 2018

The Virginian-Pilot

"The great newspaper will, by honest and intelligent journalism, inspire people to do better."

Established in 1861 | 123rd year, no. 190

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Look back on the Sports section

BRIDGE
Virginia's
Sports Page C3

the chuckle
A punchy column someone who asks questions that your spouse asks you for free.

lottery
Make: Some of last night's numbers were not correct. Call us at 757-233-6400 for the latest Virginia results and winning numbers. For latest North Carolina results, visit ncsports.com.

THE LATEST

THE PAST

get

N.C. LOTTERY

CORRE

Study: Protons pack more pressure than neutron stars

By Katherine Heifner
The Virginian-Pilot

Think you've ever pressed? Consider the proton. The inside of the subatomic particle withstands 100 decillion — yes, billion, billion — times the 33 zillion — billion, a unit of pressure, according to the researchers led by the Thomas Jefferson National Accelerator Facility.



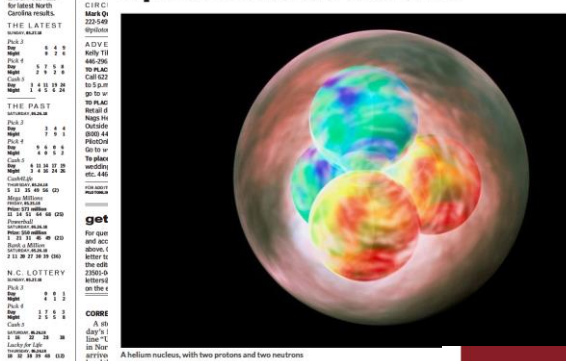
New Scientist

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DAILY NEWS 16 May 2018

We've measured the pressure inside a proton and it's extreme



A helium nucleus, with two protons and two neutrons

РИАН

ОТКРЫТИЯ ЗЕМЛЯ КОСМОС ТЕХНОЛОГИИ

Физики нашли внутри протонов самую плотную форму материи во Вселенной

16.05.2018 (обновлено: 20:01 16.05.2018)

23427 54 17



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MAY 30, 2018

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The first Americans could have taken a coastal route into the New World
MAY 30, 2018

NEWS PARTICLE PHYSICS
The inside of a proton endures more pressure than anything else we've seen
For the first time, scientists used...
MAY 29, 2018

LES FIGARO

Les pressions les plus infernales de l'Univers découvertes au cœur des atomes

l'accélérateur de particules américain a permis de déterminer les forces colossales qui s'exercent à l'intérieur du proton.

Le proton est constitué d'une mer de quarks...
C'est le chercheur américain qui a découvert que l'intérieur du proton est constitué de quarks et de gluons, les constituants de la matière ordinaire.

Les physiciens ont mesuré la pression à l'intérieur du proton en utilisant un accélérateur de particules américain. Ils ont découvert que la pression à l'intérieur du proton est plus élevée que celle que l'on trouve dans les étoiles les plus chaudes.

Ne passez pas à côté de l'Audi de vos rêves.

Du 8 au 17 juin
Journées Audi

nature **nature** **nature**

NATURE PODCAST · 16 MAY 2018

Podcast: Probing the proton, research misconduct, and making sense of mystery genes

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This week, peering inside the proton, identifying research misconduct and making sense of mystery genes.

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توزيع الضغط داخل البروتون

V. Burkert et al.

Published online: 17 May 2018

Nature (2018)
doi:10.1038/41598-018-0050-2

ملفات الصوت

يتكون البروتون - وهو أحد مكونات المادة العادية - من جسيمات أولية تُسمى كواركات، وحوالات الجوانت هي حالات الطاقة التي تربط الكواركات ببعضها البعض. والكواركات الحرة لا توجد أبدًا منفصلة أي أنها محصورة داخل الجسيمات المركبة التي تكمن فيها. يُعدُّ أصل الحصر الكوارك أحد أهم الأسئلة في فيزياء الجسيمات، والظاهرة البنية الجسيمات، وآلة محوري في كون البروتون جسيمًا متناظرًا وثنائي يور في استقرار الكون. وتختلف هذه الكواركات الأولية للبروتون بملئ تنبؤات كروماتون الاكروماتون المقيم، وهو عملية تمت فيه الكواركات التي تشكلت عن الكواركات داخل البروتون. كواركات عالية الطاقة، يُتخلف عنها بالتزامن مع الكواركات المنتجة والكروماتون المرتبطة.

قدم الباحثون - في البحث المنشور - فيينا لتوزيع الضغط الذي تتعرض له الكواركات في البروتون، وقد وجدوا أن البروتون متناظرًا تقريبًا بالقرب من مركز البروتون (في نطاق يصل إلى 0.6 فيمتومتر) ويصنّف أيضًا على أنه متناظرًا في الوسط. ويُعبر عن الضغط بالقرب من المركز حوالي 10³⁴ باسكال، وهو ما يماثل الضغط المتناظر على سطح الأرض المسماة بكثافة في الكوارك وهي التجمد البروتونية.

FEELING THE PRESSURE Extreme pressures pressure (Illustrated) as well as gluons, which hold

10 étoiles dans un proton

C'est étonnant de constater que l'intérieur d'un proton est aussi chaud que le cœur d'une étoile.

Les physiciens ont mesuré la pression à l'intérieur du proton en utilisant un accélérateur de particules américain. Ils ont découvert que la pression à l'intérieur du proton est plus élevée que celle que l'on trouve dans les étoiles les plus chaudes.

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Researchers have measured the distribution of pressure inside a proton:
on.forbes.com/6015D9ehL

상상 속 퀴크 입자 측정 성공...중성자 내부 압력의 10배

For the first time, scientists used...
MAY 29, 2018

이것이 내부 위치는 중성자 내부 물질이 바로 이러한 상태를 띠고 있다. 양자 내부 위치는 온도, 질량, 에너지, 제곱근 질량이 정해진 양자장이자 입자 상에서 자유로이 움직이는 입자 상으로 구성되어 있다. 양자 내부 위치는 온도, 질량, 에너지, 제곱근 질량이 정해진 양자장이자 입자 상에서 자유로이 움직이는 입자 상으로 구성되어 있다.

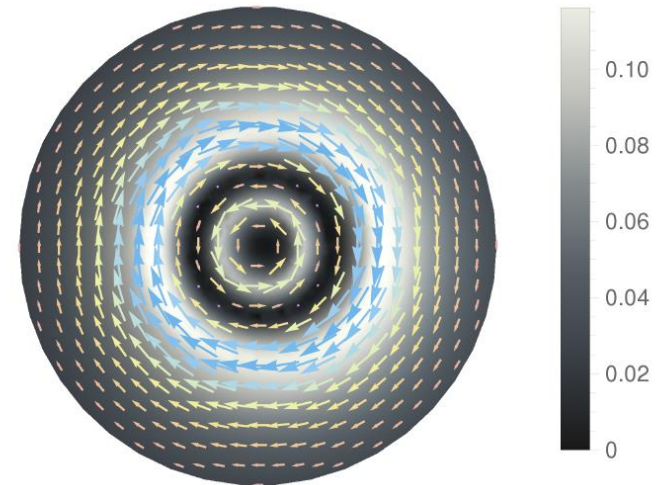
이것이 내부 위치는 중성자 내부 물질이 바로 이러한 상태를 띠고 있다. 양자 내부 위치는 온도, 질량, 에너지, 제곱근 질량이 정해진 양자장이자 입자 상에서 자유로이 움직이는 입자 상으로 구성되어 있다.

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Jefferson Lab

MECHANICAL STRUCTURE OF THE PROTON - NEXT

What can we learn about the confinement forces?



The proton's **mechanical** radius:

$$\langle r^2 \rangle_{\text{mech}} = \frac{6D}{\int_{-\infty}^0 dt D(t)}$$

where $D = D(0)$.

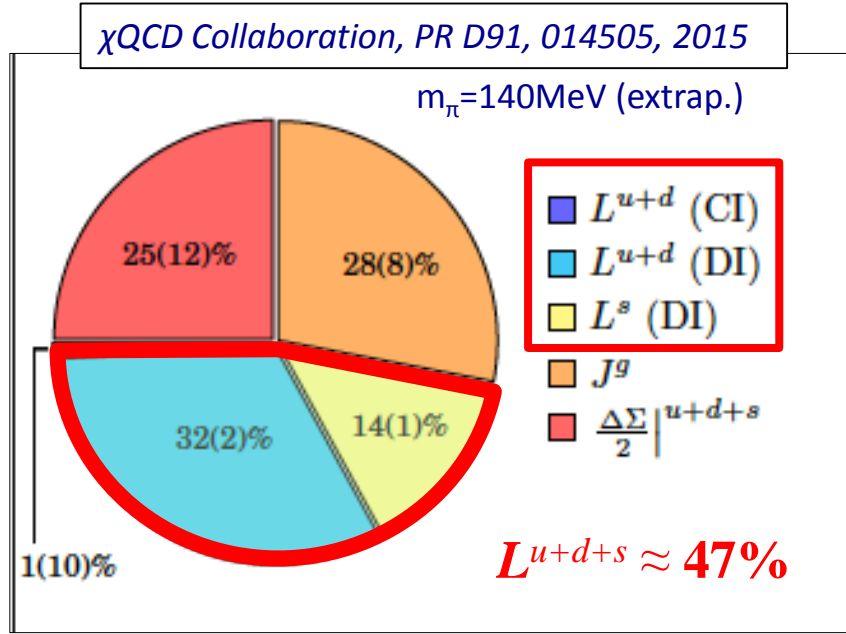


NEW TWIST ON THE PROTON SPIN PUZZLE

In LQCD, gauge invariant decomposition (X. Ji):

$$J_p = 1/2 = (1/2 \Delta\Sigma^q + L^q) + J^g$$

LQCD Predictions before 2015 showed negligible values for L^q (no DI).



Probe the OAM in accessing GPDs E^q and H^q in DVCS measurements.

X. Ji relation for quarks:

$$\int dx x [H^q(x, \xi, t) + E^q(x, \xi, t)] = 2J^q(t)$$

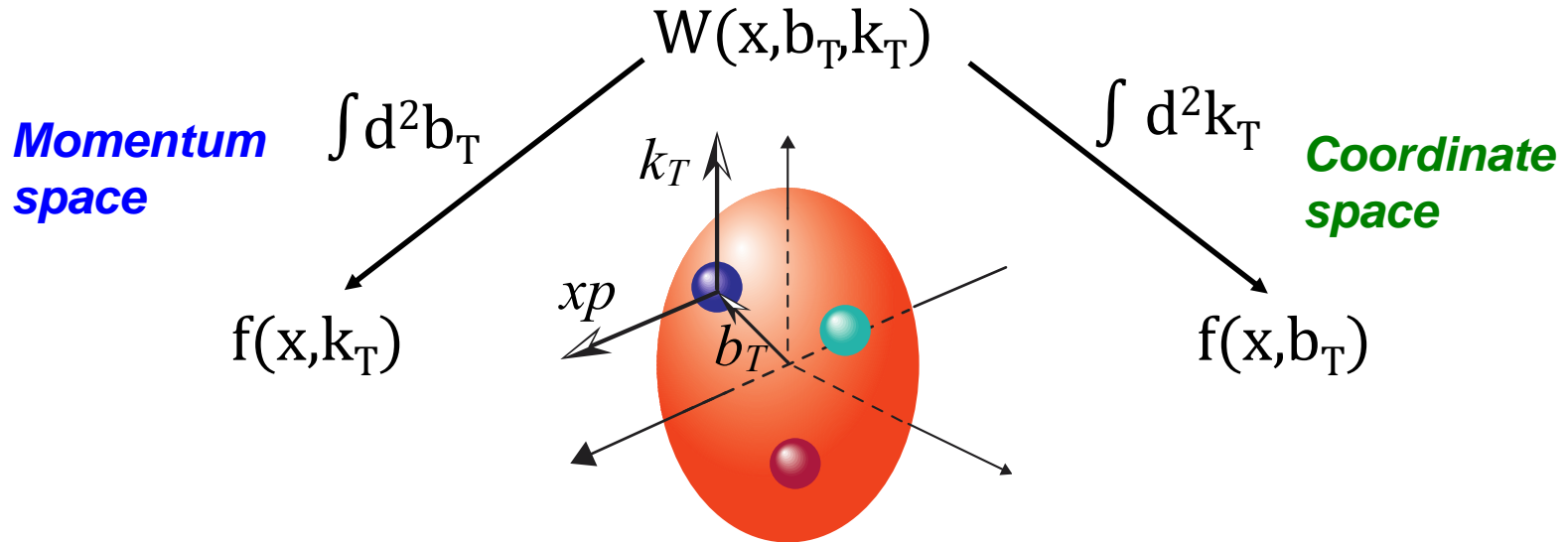
~ 50% of the proton spin is unknown

Solving the OAM puzzle must be a priority

3-DIMENSIONAL IMAGING QUARKS AND GLUONS

Wigner functions $W(x, b_T, k_T)$

offer unprecedented insight into confinement and chiral symmetry breaking.

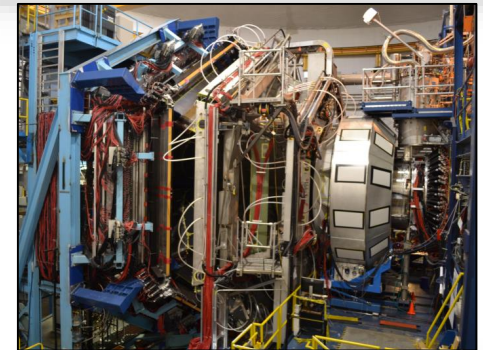
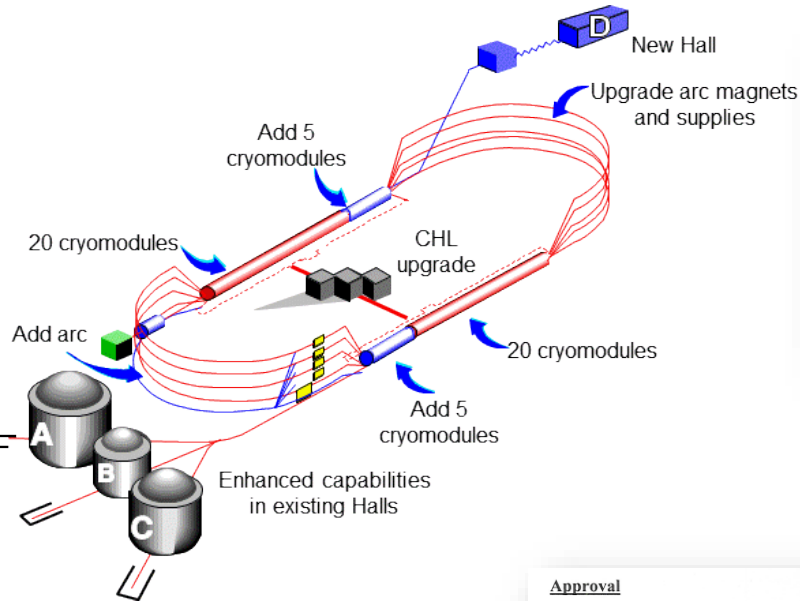


Spin-dependent 3D **momentum space** images from semi-inclusive scattering
→ **TMDs**

Spin-dependent 2D **coordinate space** (transverse) + 1D (longitudinal momentum) images from exclusive scattering
→ **GPDs**


Position and momentum → Orbital motion of quarks and gluons

12 GeV CEBAF Upgrade Project is Complete, On-time and On-Budget!



Approval

Based on the information presented above and at this review, Critical Decision 4, Approve Project Completion, is approved.



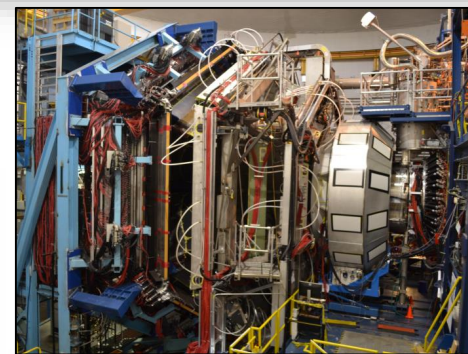
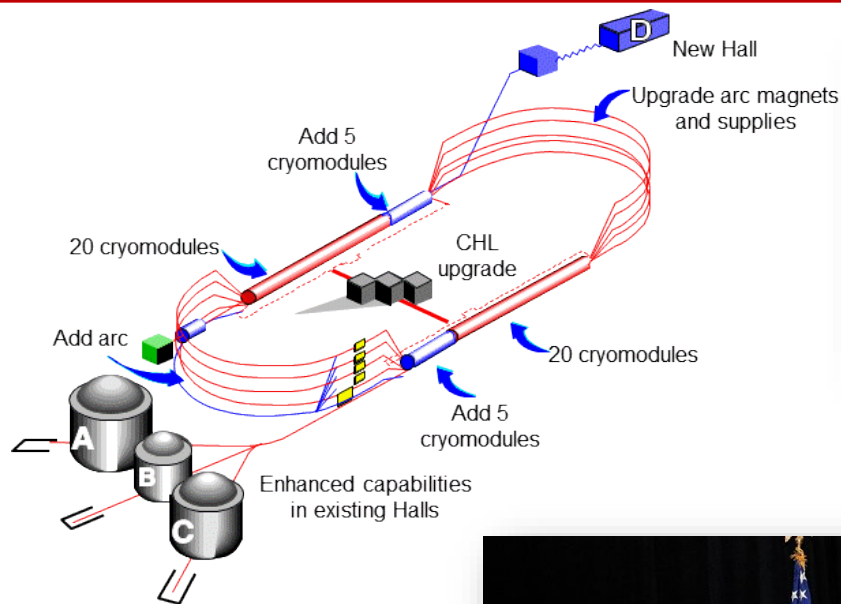
Dr. J. Stephen Binkley
Deputy Director for Science Programs
Office of Science



Date

Project Completion Approved September 27, 2017

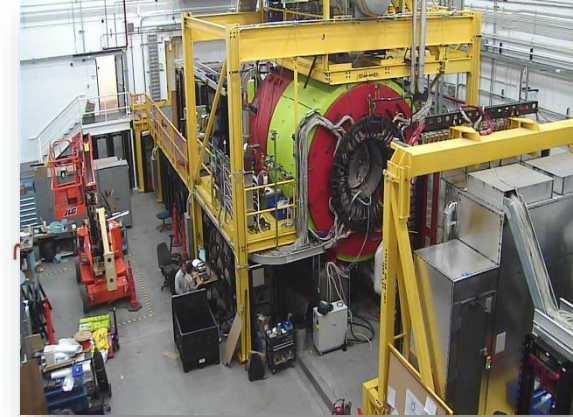
12 GeV CEBAF Upgrade Project is Complete, On-time and On-Budget!



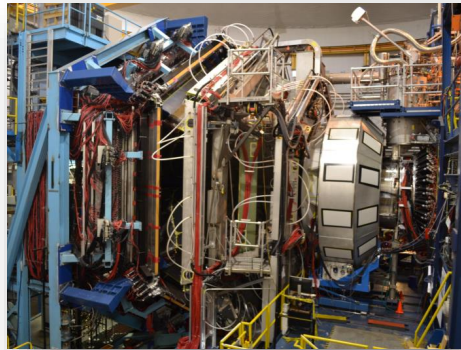
Project Completion Approved September 27, 2017

12 GeV Scientific Capabilities

Hall D – exploring origin of **confinement** by studying **exotic mesons**



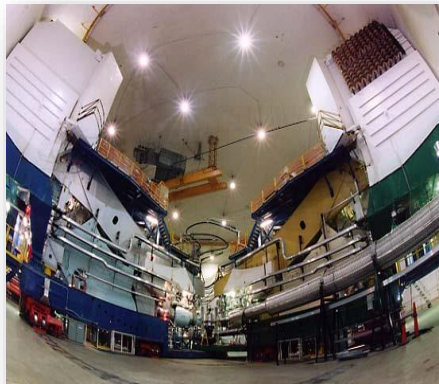
Hall B – understanding **nucleon structure** via **generalized parton distributions** and **transverse momentum distributions**



Hall C – precision determination of **valence quark** properties in nucleons and nuclei



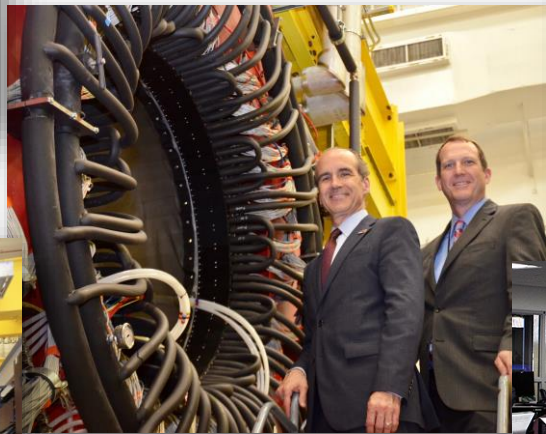
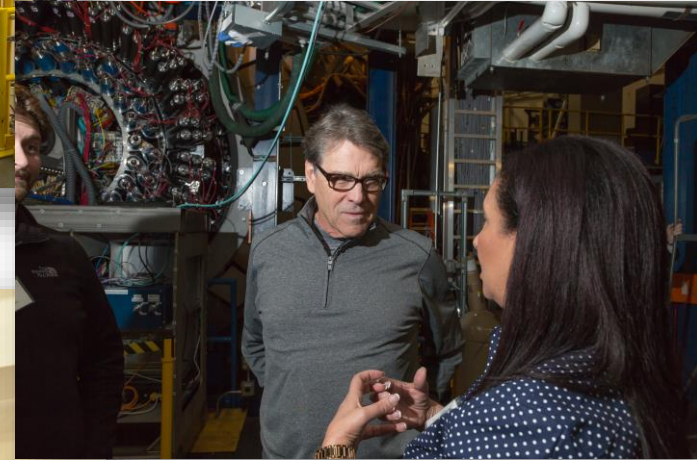
Hall A – short range correlations, form factors (SBS), hyper-nuclear physics, **future new experiments (e.g., SoLID and MOLLER)**



12 GeV Has Been Officially Dedicated by the DOE



Keeping Jefferson Lab front and center: *DOE Secretary and Under Secretary visits*



The 2015 Long Range Plan for Nuclear Science

RECOMMENDATION I

The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. The highest priority in the 2015 Plan is to capitalize on the investments made.

- *With the imminent completion of the CEBAF 12-GeV Upgrade, its forefront program of using electrons to unfold the quark and gluon structure of hadrons and nuclei and to probe the Standard Model must be realized.*
- **Operate 12 GeV CEBAF – highest priority**

RECOMMENDATION II

We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.

RECOMMENDATION III

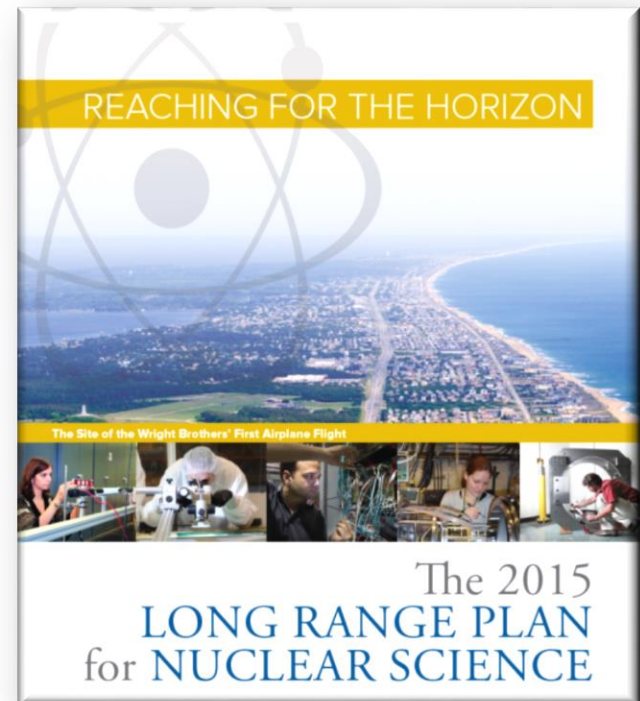
We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

- **Jefferson Lab EIC (JLEIC) development**
- **BNL (eRHIC) development**
- **National Academy of Sciences report expected**

RECOMMENDATION IV

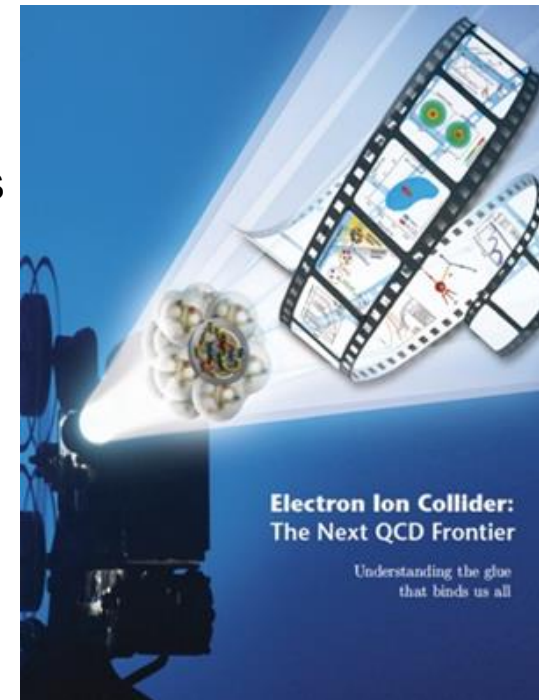
We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.

- **MOLLER (CD-0), SoLID (pre-conceptual)**



THE LONGER TERM FUTURE OF QCD RESEARCH: AN ELECTRON-ION COLLIDER

- Proton (and nuclei) and black holes are the only fully relativistic (high enough energy density to excite the vacuum) stable bound systems in the universe. Protons can be studied in the laboratory.
- Protons are fundamental to the visible universe (including us) and their properties are dominated by emergent phenomena of the self-coupling strong force that generates high density gluon fields:
 - The mass of the proton (and the visible universe)
 - The spin of the proton
 - The dynamics of quarks and gluons in nucleons and nuclei
 - The formation of hadrons from quarks and gluons
- The study of the high density gluon field that is at the center of it all requires a high energy, high luminosity, polarized Electron Ion Collider



The 2013 NSAC *Subcommittee on Future Facilities* identified the physics program for an Electron-Ion Collider as *absolutely central* to the nuclear science program of the next decade.

NAS STUDY OF THE EIC SCIENCE CASE

THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE

Division on Engineering and Physical Science

Board on Physics and Astronomy

U.S.-Based Electron Ion Collider Science Assessment

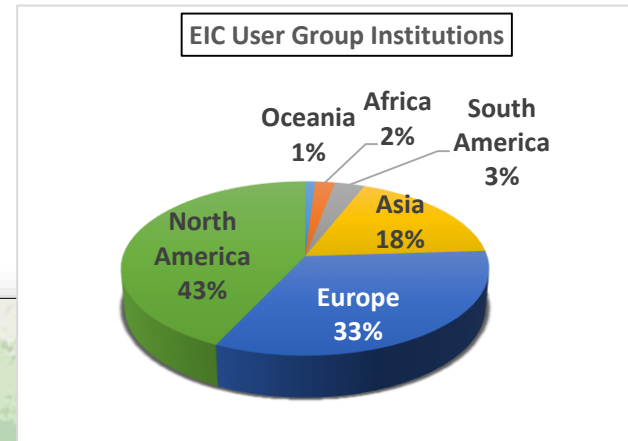
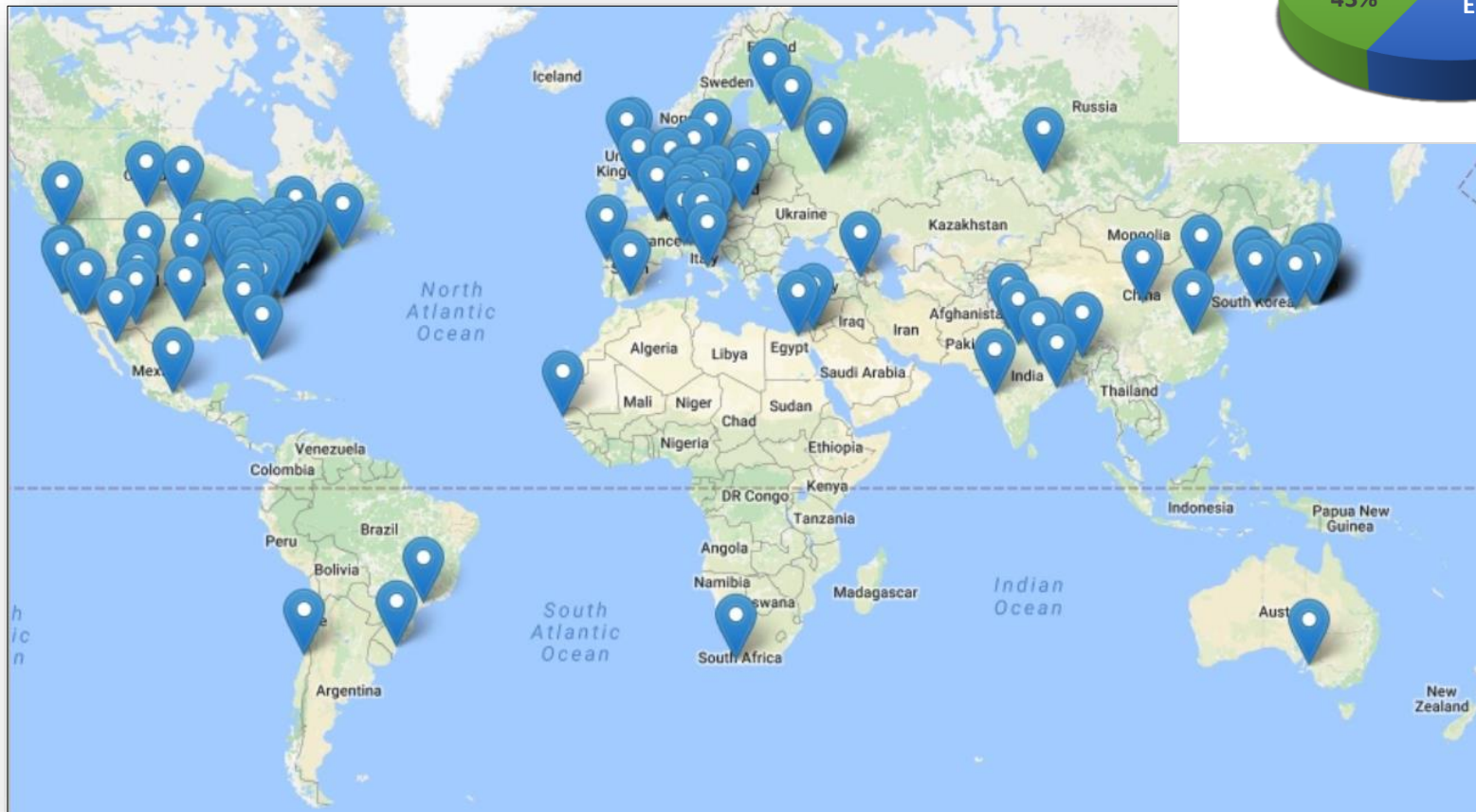
Summary

The National Academies of Sciences, Engineering, and Medicine (“National Academies”) will form a committee to carry out a thorough, independent assessment of the scientific justification for a U.S. domestic electron ion collider facility. In preparing its report, the committee will address the role that such a facility would play in the future of nuclear science, considering the field broadly, but placing emphasis on its potential scientific impact on quantum chromodynamics. The need for such an accelerator will be addressed in the context of international efforts in this area.

“U.S.-Based Electron Ion Collider Science Assessment” is now nearing completion.

EIC Users Group and International Interest

Formed in fall 2015, currently: 788 members
169 institutions, 29 countries



Summary

- Lepton scattering is a powerful tool to probe the rich internal structure of the nucleon
- A new perspective on exclusive reaction physics opens a new avenue to test Confinement Mechanism
- Access the partonic Energy Momentum Tensor
- Three-dimensional imaging of nucleon helps solve remaining puzzle to the proton spin, and uncovers the rich dynamics of QCD
- Exciting times at the beginning of the 12 GeV high precision era has started
- Electron Ion Collider – A new QCD frontier

Thank
You



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